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Revolution of Malaysia's Kaolin to Metakaolin towards various application: A Mini Review

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ABSTRACT

The transformation of kaolin to metakaolin was studied in various state in Malaysia which is Segamat, Nitar, Lenggor, Ipoh, Bidor, Mersing, Sabah, and Sarawak. In Segamat, the kaolin has a light colour due to the high silicate composition and also contain high mineral such as kaolinite and quartz existed as impurities. Aluminum rich kaolin is bright in color with elevated plasticity and is commonly used in the ceramic, plastic, dye, fabric, pesticide, pharmaceutical and beauty industry. For Nitar and Lenggor, production of metakaolin occurs at 510°C and formation of mullite occur at 900°C. Both clays show good crystallization of pseudohexagonal to hexagonal kaolinite particles. Moreover, the classification of clay and the sizing are the significant characteristic to be determined using the method of the beneficiations. The method of beneficiations is crucially important to increase the quality of clay to meet the requirement for industry application. In Ipoh and Sarawak, the primary deposit is dominated by kaolin and the mixture of granites and diorites produced from weathering. On the other hand, in Bidor, the primary deposit is a mixture of kaolinite, muscovite and smectite also formed by weathering. The increasing amount of illite in secondary kaolin deposits in the Mersing area due to the marine deposition of those deposits where illite formed by the absorption of clay minerals from the seawater by pottasium. Kaolin in Kg Gading, Bongawan Sabah were treated with sodium hexametaphosphate to remove impurities in natural kaolin. The transformation of kaolin to metakaolin was conducted at 800°C for 5 hours.

INTRODUCTION

Clay is a common name used to describe a finely grained weathered material which is <63 μm. It contains clay minerals that have microscopic structures such as kaolinite and montmorillonite in which these structures provide clay its plasticity properties [1]. According to Hussin et al. [2], clays can be divided into several types based on the natureand its content of mineralogy such as ball clay, bentonite, and kaolin. Generally, this clay mineral is used for conventional art of sculpture, pottery and other household crafts. Industrially, the kaolin type of clay is used as absorbent and filter material in the petroleum industry as well as nanotechnology in the high technology industry. This industrial potential accords the kaolin to be widely studied. According to Department of Mineral and Geoscience, Malaysia from 1985 to 2005, approximately 112 million tonnes of kaolin deposits have been recognized across the nation in the countries of Perak, Johor, Kelantan, Selangor, Pahang and Sarawak. The output of kaolin improved to 587,508 tonnes in 2007 from 341,223 tonnes generated in 2006. Kaolin is a secondary mineral origin as a result of the method of weathering the main minerals. The main component of kaolin is fine grain kaolinite which is <2 μm. Also, other components such as aluminum and iron phyllosilicate. Aluminum wealthy kaolin is bright in color with elevated plasticity and is commonly used in the ceramic, plastic, fabric, fabric, pesticide, pharmaceutical and beauty industries [3]. The need for a raw materials in the pottery manufacturing industry is increasing due to the rapid development of the construction sectors [3]. Khor [4] reported the use of kaolin in Malaysia involving brick, cement, wall and floor tiles, clay plates, ridge tiles, vases, sanitary articles and others. The mixing of domestic and foreign clays is sometimes used to achieve standards in a clay-based manufacturing industry. Therefore, the study to obtain blending techniques that no longer require imported clay is something that is important for the purpose of cost savings [4].

Kaolin is also defined as a kaolinite minerals in excess of 50 % and contains very low impurities [5]. In Malaysia, clay is used in the ceramics industry which are traditionally processed. The processing of clay is aimed at getting the higher grade for domestic use and for export. Clay is also used for the production of tiles, porcelain and electromagnetic insulator, filler and coating materials [6]. Harben and Bates [7] defined kaolin as plastic clay, white, containing a well-made kaolinite and has low iron content. Kaolin is formed from the alteration of crystalline stones such as granite [7]. This change occurs either by hydrothermal or weathering or both. The kaolin from Malaysia were analysed to determine their mineralogical and composition which represents the primary and secondary deposit of kaolin. Besides, this to investigate the effect of source rock on the mineralogy of the primary kaolin. Also, those are being compared with the secondary deposits. In Ipoh and Sarawak, the primary deposit is dominated by kaolin and the mixture of granites and diorites. On other hand, in Bidor, the primary deposited is a mixture of kaolinite, muscovite and smectite. Commonly, the paper industry uses a kaolin for the coating and as a filler due to its characteristic. In addition, the other applications of kaolin including ceramic, paint, rubber, plastic, fiberglass, medical and cosmetic industry. In particular, the use of kaolinite is as follows: the paper industry (45 %), the refractory and ceramics sector (31 %), the fiberglass sector (6 %), the wood sector (6 %), the paint sector (3 %) and the others (4 %) [8]. The use of clay for therapeutic reasons is also widespread [9-12] and is dependent on well-known positive consequences found after tests and errors [13] or on a clinical-biological basis [14]. According to Gomes and Pereira Silva (2007), there are many examples of clay minerals in pharmacy and cosmetics that indicate the wide range of these products as effective values, adsorbents, suppliers, for the shipment of drugs and for retarded formulations [15]. For instance, the use of clay as a medication distribution system: opportunities and limitations [16], use of clay minerals in semi-solid wellness care, pharmaceutical plans, using minerals as carrier-releasers of effective components and can usually be administered orally to the person. Indeed, some drugs such as antibiotics adsorbed to clay mineral phyllosilicates (e.g. talc, kaolin) are implemented to the skin such as new, bleeding-free injuries, wounds need refrigeration.

Table 1. The chemical composition of various kaolin in Malaysia.

Kaolin in Malaysia	Chemical Composition
Nitar	Quartz, kaolinite, mica
Lenggor	Quartz, kaolinite, mica,albite
Ipoh	Quartz, kaolinite,bayerite
Bidor	Quartz, kaolinite, muscovite, smectite
Mersing	Quartz, kaolinite, illite
Sabah	Quartz, kaolinite, mica
Sarawak	Quartz, kaolinite

The properties of clay should be carefully identified and characterized so that the clay can be used according to its standard to avoid wastage [19]. Therefore, the determination of clay characterization is important for assessing potential usability. Calcination is a method to increase brightness, light scattering, hydrophobic properties, dielectric properties and kaolin hardness [20]. The following reaction will be occurring when kaolinite minerals are calcinated as follow;

$$\text{Kaolinite } (Al_2Si_2O_5(OH)_4) \xrightarrow{\sim 550^{0}C} \text{Metakaolin } (Al_2Si_2O_7)$$

$$\xrightarrow{\sim 900^{0}C} \text{Amor phase}$$

$$\xrightarrow{1000^{0}C - 1100^{0}C} \text{Mullite } (Al_6Si_2O_{13})$$

Metakaolin and lime will have reacted well with the presence of hydrated calcium and aluminum silicate [21]. Metakaolin produced from calcination at temperatures of ~ 900 ° C to 1100°C is used in various industries such as paper industry, PVC, wire and cable coating, rubber industry, plastic, adhesive, polishing agent [22].

Around 60 % to 70 % of the world's kaolin is used for the paper industry while the rest for other industries [12]. The world's largest kaolin producer (regardless of whether it was processed or raw) in 2009 was the United States, Uzbekistan, Czeck Republic, Germany, Brazil, Ukraine and Britain. The total world production of kaolin is 30.6 million tones' which was lower than 2008 due to a decrease in demand for products paper [23]. Kaolin demand since 1998 is seen to be decreasing due to the use of calcium carbonate (GCC / PCC) as filler and coating. Calcium carbonate is fast competing with kaolin to obtain a brighter product as well as due to transportation cost factors. However, this decline is expected to slow with the development of the paper industry in China [24]. In Malaysia, the highest kaolin production is in four states namely Perak, Pahang, Johor and Selangor with 31 total of factory [25]. Table 1 show the total production of kaolin in Malaysia.

In Malaysia especially in Johor, exploration of clay has been done by some researchers in the area as shown in Figure 1.

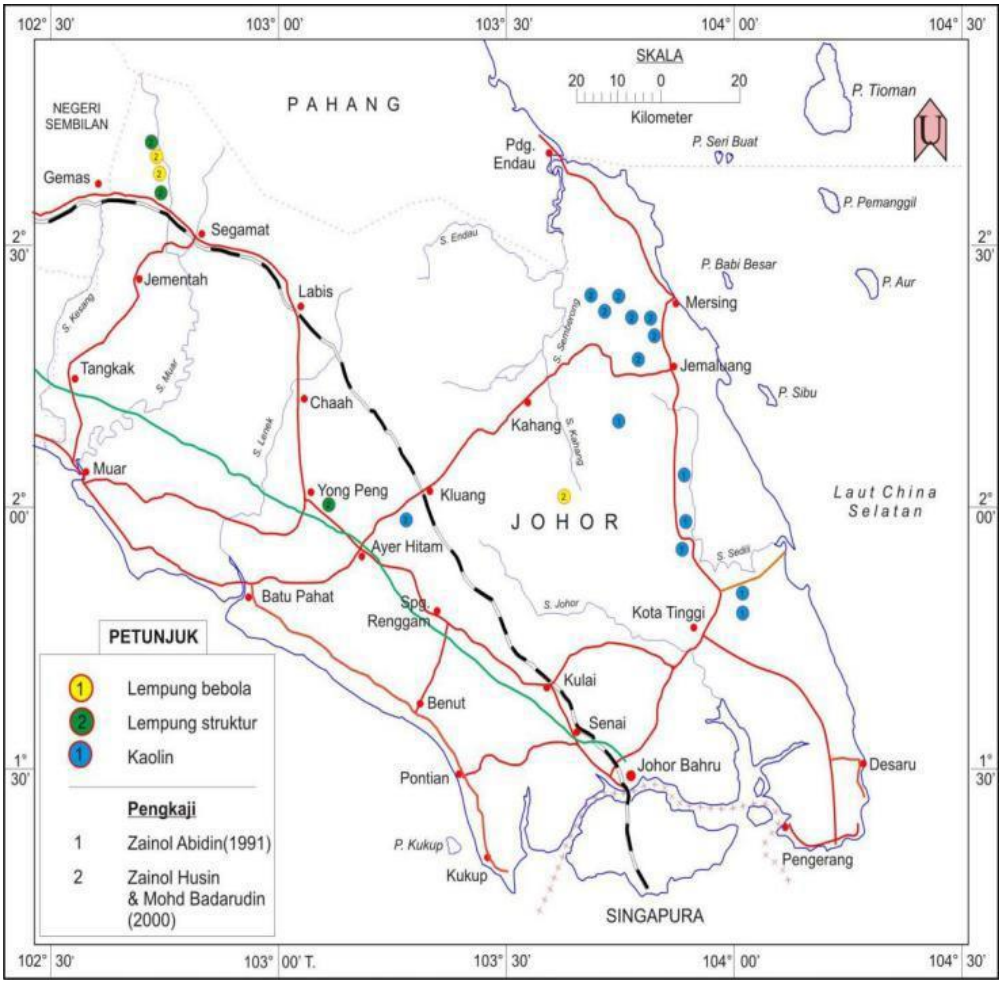

Figure 1. Location of clay survey by previous researcher in State of Johor.

Hussin and Hasan [26] examined the chemical properties, mineralogy, physical and clay sample combustion at the stage of follow-up exploration and identified the amount of clay resources in the state of Johor including the Nitar area. A total of 6.86 million tons balls of clay, 24.81 million tons of structural clay and 5.06 million tons of kaolin have been identified.

TRANSFORMATION KAOLIN TO METAKAOLIN

Kaolinite Buloh Kasap Segamat samples were taken and brought to the laboratory and dried at room temperature for about two weeks. The dried sample was crushed with a mortar and placed in an oven and heated at 105 °C and the raw sample was left for one day. The pellets are prepared from the raw samples for analysis of the major elements with samples in the form of powder that are dried at 105°C for an hour and transferred to a platinum bowl before heated in the furnace at a temperature of 1000-1100 °C for calcination process [3]. For the Nitar and lenggor kaolin, it was dried at 80°C for 4 hours. The sample then will be crush at <63 micro meters (ɥm) and calcination at temperature 500, 700 and 1100 °C for 4 hours [2].

Repetitive kaolin samples were collected from the primary kaolin deposits of different source rocks from Ipoh, Bidor, and Sarawak as well as a secondary kaolin deposit from the Mersing area. The clay fractions have been segregated by boiling kaolin samples in distilled water for about 2 weeks. The samples were handled three occasions with ultrasound for 10 to 15 minutes each using an ultrasound washing device. The clay fractions (< 2ɥm) were separated from the aqueous suspensions after approximately 7 hours from the sedimentation experiment of grain size analysis to ensure their purity. The clay fractions were precipitated and dried on glass slides to investigate the clay mineralogy of the studied deposits [27]. 10-kilogram sample of kaolin clay was procured from Kampung Gading Bongawan, Sabah. Sedimentation of raw clay was done by stirring a mixture of 1L distilled water with 500g raw clay and deflocculant for 10 minutes. The 2.5wt (%) of sodium hexametaphosphate was used as deflocculant during sedimentation process. The mixture of the raw clay and sodium hexametaphosphate was stirred and let to settle down before the supernatant was separated. Supernatant then was dried at 100°C overnight. The treated clay undergoes metakaolin at temperature of 800 °C [28].

FUTURE PERSPECTIVE

The colour of the Segamat kaolin was bright owing to its elevated silicate structure. Kaolinite is the largest mineral concentration of kaolin and quartz. The small quantity of contraction has shown that the kaolin is dense with confined spaces,so the ceramic industry may consider it very appropriate for use. Needless to say, this kaolin has a small absorption of heat, plasticity and durability according to the rupture modulus experiment. Low concentrations of arsenic connected with toxicity make Segamat kaolin very appropriate for use in the ceramic industry. The proportion of water absorption is also small relative to other clay, so that the kaolin investigated is classified as less water permeable. However, Segamat Kaolin is regarded to be less appropriate for use in the ceramic industry, which includes many models owing to its poor plasticity characteristics through plasticity screening.

The different between Nitar clay and Lenggor are the sedimentation rate and viscosity where the Leggor clay has high viscosity and low sedimentation rate opposites to Nitar clay. Also, the Nitar clay and Lenggor clay have similarities on the high crystallization rate of pseudohexagonal to hexagonal kaolinite particles. Moreover, the classification of clay and the sizing are the significant characteristic to be determined using the method of the beneficiations. The method of beneficiations is crucially important to increase the quality of clay to meet the requirement for industry application. For the classification, the Lenggor clay is a form of kaolin clay whereas the Nitar clay is from the mica-rich cycloid clay. Most of the clay contains mineral such as kaolin, mica-rich cycloid/Illit and quartz but the difference between each clay is which mineral dominant inside. The predominance of kaolinite in the Ipoh and Sarawak deposits is due to the relative abundance of feldspar minerals (more Al) in the granite and diorite source rocks in these two regions. Conversely, the formed of smectite and muscovite in the primary deposits of kaolin from the Bidor area represents the mineralogical composition of the parent rock in the mica-schist region. The growing number of illite in secondary kaolin deposits in the Mersing owing to the marine deposition of those soils, where an ilite developed by the absorption by K of clay minerals from seawater. In the secondary clay, there is high clay mineral content compared to the quartz. As a result of comparative enrichment of the fine fractions during the transfer from the source to the deposition site. Furthermore, the presence of smectitis and muscovite in the mineralogical structure of the main reserves of kaolin from the Bidor area, which were originated from schist can be attributed to the original composition of schist and/or the less intensive weathering of these rocks. Assuming that the studied primary kaolin deposits are located more or less in the same geographical provenance and therefore were formed under more or less similar paleoclimatic conditions, the compositions of the primary source rocks of these deposits could be the controlling factor of the mineralogical compositions of the studied deposits. The reason of many of illite formed on the Mersing area because of the higher of potassium in the sea water itself. Currently, the precise studies on mineralogical and geochemical conducted on the clay fractions of those sediments in addition as their supply rocks to clarify the impact of supply rock compositions on the geology and chemistry of the clay geology of the clay soils created once these rocks.

The presence of kaolinite clay in the Lampas region is common. The scientific proof supported by mineralogical and chemical analyses appears to suggest that Lampas kaolin is a product of both hydrothermal and in-situ aplite, leucomicrogranite, pegmatite and medium to coarse-grained porphyritic granites. Various events of quartz, feldspar and illite / muscovite happen subserviently and haloysitis happens locally. In term of physically and chemically characteristic, the Lampas kaolin clay has excellent performance that can fulfil the requirement and specifications of industry. Aforementioned the kaolin clay has been shown to have small concentrations of iron oxide, titanium, complete alkali material and to have great brightness before and after firing. Below 75 μm of kaolin tended to have low workability index, modestly for shrinkage properties and MOR scores and appropriate oil consumption. Moreover, with the better density percentage, these characteristics could be enhanced. There are over than 90 percent and 45 percent of the natural Lampas rock volume fractions are below 20 μm and 2 μm, combined, with retrieval rates measured at around 30 to 50 percent. Lampas kaolin is usually appropriate for various industry and applications.

CONCLUSIONS

Both Lenggor clay and Nitar clay contain kaolin, mica-rich, quartz. The difference between both are the percentage of the mineral contain. The Nitar clay is classified as mica-rich clay due to high mica-rich content with 39% while Lenggor clay is classified as kaolin. There is low mineral contain inside both Lenggor and Nitar clay such as iron oxide (<1.35%), titania (<0.99%) and low organic matter (<1.5%) causes both clays have the brightness> 94% suites the minimum criteria for paper and ceramic industry. Calcination at 1100 ° C improved the brightness of Lenggor clay by about 0.25 percent, but the brightness of Nitar clay reduced by about 0.72 percent. Calcination produces a refractory mineral, which is 900 ° C mullite in the Nitar but cannot be identified in Lenggor clay [2].

The predominance of kaolinite and the absence of the other clay minerals such as illite, smectite, or mixed-layers clay minerals in the kaolin deposits formed give a result of granites and diorite weathering in the Ipoh and Sarawak areas, respectively. It can also be related to the primary composition of granites and diorites and to intensive weathering conditions. In the secondary clay, there is high clay mineral content compared to the quartz. As a result of comparative enrichment of the fine fractions during the transfer from the source to the deposition site Detailed mineralogical and geochemical investigations on the clay fractions of these deposits as well as their source rocks are undertaken now to clarify the effect of source rocks compositions on the mineralogy and geochemistry of the clay mineralogy of the kaolin deposits formed after these rocks [27].

Segamat kaolin generally have very high silica and silicate composition through the presence of quartz and kaolinite minerals that cause the color to be white and bright. Low content of arsenic makes Segamat kaolin suitable for use in the ceramic manufacturing industry. High quartz content is also found in kaolin samples as impurities. In addition, it is best suited to make ceramic because of its high heat resistance. In addition, the percentage of water absorption is low compared to other clay so that kaolin studied is categorized as less permeable water [3].

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